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CHEMICAL THINNING of Deciduous Tree Fruits

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SUMMARY

THINNING apple and other tree fruit by means of chemical sprays, to get fruit of better size and finish and to achieve annual rather than biennial bearing, has been a growing practice in the United States for 10 years or more.

The use of dinitro compounds (mainly in the West) and hormone-type sprays (mainly in the East) has been characterized by quite variable results--from one variety of fruit to another, from one orchard to another, from one year to the next. Yet the economic need for low-cost thinning methods to substitute for most of the expensive hand thinning is so great that spray thinning has been widely accepted by commercial growers.

Horticultural research has revealed much about the action of these sprays, but a great deal remains to be ascertained, especially about the chemical mechanism that makes the spray thinners behave as they do. Scientists have laid down general ground rules for the application of these sprays, but growers still must depend on their own judgment as to conditions in particular orchards for practical use of thinning sprays.

CHEMICAL THINNING OF DECIDUOUS TREE FRUITS

BLOSSOM or young fruit thinning of apple and other deciduous tree fruits with chemical sprays has been a growing practice in commercial orchards of the United States for more than 10 years.

The principal value of such sprays is to improve size and finish of the fruit and to break up biennial bearing, or "on" and "off" years of heavy and light fruiting, thus making annual crops larger and more uniform. Other advantages include the decreased cost of spray thinning compared with hand thinning, and the need for less hand thinning.

Although much has been learned about chemical sprays for thinning, much remains to be ascertained about the actual mechanics of their operation on living trees. Their use is beset with complexities and hazards. Identical applications on the same trees in succeeding years may have very different results. Yet the use of these sprays is of such economic value that fruit growers have been willing to employ them despite the variability in results. Variation in results may be caused by timing of application, weather conditions, vigor of trees, concentration of spray material, varieties treated, thoroughness of pollination, winter injury, frost damage, and other factors.

Chemical thinners add another to the arsenal of sprays already used by commercial orchardists to produce marketable fruits. Insecticide and fungicide sprays are used to control insects and fungus diseases, nutritional sprays are sometimes applied to the dormant tree or to the leaves to make better-nurtured trees, and sprays are used to keep fruit from dropping until the orchardist is ready to pick it. Some of the stop-drop sprays (see ARS Special Report 22-28, Use of Stop-Drop Sprays on Apples and Pears) are identical with some sprays used for chemical thinning. Thinning sprays are generally not recommended for use in combination with other spray materials that require uniform coverage; blossom-thinning sprays are best used selectively from tree to tree.

Spray-thinning research started in the depression years of the early 1930's. Growers wanted a spray that would entirely defruit apple trees of varieties that would not pay their way. This forestalled the expense of spraying and harvesting a crop for which there was no market. After this initial venture in total crop removal, emphasis passed to finding spray materials that would break up biennial bearing in varieties having that tendency. Early thinning was done with sodium dinitro cresylate and related dinitro compounds. These still are largely used in the West. Later the hormone-type materials, particularly naphthaleneacetic acid (NAA), used originally in orchards to delay harvest drop, were found to be effective for thinning after the blossom stage and after the danger of frost had passed. NAA and related materials have been most popular in the East.

Of course, fruit trees do a partial job of thinning themselves. Usually not more than 5 to 20 percent of the apple blossoms set fruit. Thinning may be required to reduce fruit set by a relatively small percentage of some varieties. It is especially needed on varieties that tend to "snow-ball" blossoming and to biennial bearing habits. Growers have found chemical thinning profitable, lowering hand-thinning costs from one-fourth to nine-tenths. Hand thinning of heavily loaded trees may cost \$75 to \$200

per acre, compared with \$5 or \$6 an acre for the spray application. Thus, even if the chemical spray does not do a complete thinning job, and some hand thinning is necessary, the saving in cost may be substantial.

CHEMICAL SPRAYS USED ON APPLES

Dinitro Sprays in the West

HAND THINNING developed early in the apple-growing industry of the Northwest. Its purpose was to help produce a high-quality crop. However, it is one of the costliest operations in the production of fruit. Depression-born research using dinitro compounds to defruit unprofitable varieties and later work to reduce biennial bearing indicated the feasibility of using chemical sprays for fruit thinning that could be applied with orchard equipment already in use.

The pollination situation in a variety or in an orchard is an important factor in the successful use of chemical thinning. Some varieties of apples are partially self-fruitful--that is, they set some fruit with their own pollen. These include Golden Delicious, Jonathan, Rome Beauty, Yellow Newtown, and York Imperial. Other varieties, among them the Delicious, Grimes Golden, McIntosh, Stayman, and Winesap, are self-unfruitful, requiring pollination by another variety. Partially self-fruitful varieties require a 50 to 100 percent higher concentration of dinitro sprays than self-unfruitful varieties for successful thinning. This complicates spraying operations, because sprays of different concentration vary in their effects on different varieties. In addition to providing pollinator varieties in every second or third row of trees, growers also place colonies of bees in the orchards to carry the pollen from tree to tree. Chemical thinning normally takes place after a period of bee activity.

Since one of the important values of chemical spraying is to break up biennial bearing, the sprays are most useful on strongly biennial varieties. Some varieties, as long as the trees remain in a vigorous condition, are easy to keep on an annual basis. Among the easiest are McIntosh, Rome Beauty, and Stayman; they seldom overbloom, hence need least spray thinning. Varieties that have a strong tendency to become biennial include Baldwin, Golden Delicious, Wealthy, Yellow Transparent, Yellow Newtown, and York Imperial. Intermediate between these two groups are Delicious, Grimes Golden, Jonathan, Rhode Island Greening, and Winesap. A grower has to know the condition of his trees, because all varieties of apples, when they are not vigorous, tend to become biennial. Therefore, trees not in the best condition may stand more in need of spraying to prevent the biennial tendency, but they are also more susceptible to its effects and can easily be overthinned.

Dinitro sprays appear to work in various ways to reduce fruit set. Pollen on unfertilized blossoms may be killed when the spray is applied from 1 to 10 hours after pollination, depending on the weather. Pistils in freshly opened blossoms may be killed or injured. Petals of unopened buds may be injured enough that they may not open to expose the pistils of pollination. Chemical sprays are also believed, by indirect action, to prevent many fertilized blossoms from developing because of shock to the trees or temporary changes in the growth processes. Dinitro sprays must be applied at or right after the bloom stage to be effective in reducing set. About the same amount of thinning may be obtained from the full bloom stage to 3 or 4 days following. Sprays applied after the bloom period usually have little effect on fruit set.

Results and Recommendations

Considerable variability of results has been characteristic of the experience with blossom-thinning sprays. Identical procedures in the same orchard may produce results that vary in different years from little thinning to serious overthinning. Weather before and after application of the spray overshadows all other variables. Weather before application can be observed, but weather for a few days thereafter is not predictable with sufficient accuracy for most satisfactory results.

Chemical thinning has been in operation long enough that researchers can begin to average out the results. At Wenatchee, Wash., in experiments conducted cooperatively by Federal and State research agencies, a block of Delicious apples, a self-unfruitful variety, has been given identical treatment for 10 years, from 1946 to 1955. Timing, method of application, and concentration (1-1/3 pints of sodium dinitro cresylate in 100 gallons of water) were the same. Results were generally favorable in 7 of the 10 years. Overthinning resulted in 1951 because of frost following spray treatment; it has been established that frost or near-frost temperatures cause much greater thinning on trees sprayed with dinitro materials. Overthinning occurred in 1953 and 1955 because of rainy weather after the trees had been sprayed; wet weather seems to make the trees absorb much more of the chemical, and the results can be drastic.

Sprayed fruits over the 10-year period were larger--82 apples per 33 pounds as compared with 98 per 33 pounds for the untreated check trees. And the percentage of bloom the following year was far larger--61 percent for sprayed trees as compared with 38 percent for those not sprayed.

Grower experience and the results of many detailed experiments elsewhere have been in line with the results obtained in this experimental block. A spray concentration that is satisfactory most years when weather is favorable--moderate temperatures and generally clear days--may greatly overthin if frost or rain follows the application of the dinitro sprays. For this reason, the recommended concentration of dinitro sprays is low enough that only a partial thinning job is done in years of favorable weather; this is followed by hand thinning as required. Partial chemical thinning greatly reduces the amount of hand thinning necessary, thus reducing costs as compared to total hand thinning. Early partial chemical thinning also appears to induce an adequate bloom for the year following.

Recommendations for chemical thinning in the West, based on wide research and field experience, were made in 1955 by an ARS scientist at Wenatchee, Wash., working with the Washington Agricultural Experiment Station.¹ Chemical thinning, he said, should be used in such a way as to reduce as many hazards as possible. It should be used as a supplement to hand thinning rather than as a substitute. "When sprays happen to result in just the right amount of thinning they are precariously close to overthinning." The recommendations are conservative, aimed at avoiding overthinning under nearly all conditions of reasonable pollination and tree vigor. Underthinning can be corrected, but overthinning cannot be rectified during the same crop year. Overthinning may result in rare instances if the ARS recommendations are followed, but the average over a period of years promises greater benefits than risks.

¹L. P. Batjer, Principal Physiologist, Tree Fruit Experiment Station, Wenatchee, Wash., "Re-Evaluation of Chemical Thinning," in Proceedings, Washington State Horticultural Association, 1955, pp. 169-71.

- ¶ Sodium dinitro cresylate should be used at a concentration of 2/3 pint per 100 gallons of water on self-unfruitful varieties (Delicious and Winesap). Forty-percent DNOC (4, 6-dinitro-o-cresol) powder may be used at a concentration of 1/3 pound per 100 gallons of water. For partially self-fruitful varieties (Golden Delicious, Jonathan, Yellow Newtown) the concentration should be increased 50 to 100 percent.
- ¶ Dilute sprays are preferred to concentrated. In machines using the air-blast system, the concentration may be doubled but greater than double strength should be avoided.
- ¶ Self-unfruitful varieties should not be sprayed if they are more than 2 tree spaces away from pollinizers.
- ¶ Each variety of apples should have only one application of the spray.
- ¶ Spraying the lower third of the tree should be avoided if possible. Normal set on lower branches is lighter than on those having better exposure to sunlight. Furthermore, some spray normally drips from the higher branches onto those below.
- ¶ Spraying should begin, if weather conditions are favorable, when 3 blossoms per spur cluster are open on the north side of the tree. Less risk is involved from weather changes if a given block of trees is sprayed over a 3- or 4-day period.
- ¶ Naphthylacetamide may be used instead of dinitro sprays at the late bloom or calyx stage at a concentration of 50 parts per million of water. This hormone material is generally milder in action than dinitro sprays and is particularly adapted for use when cool and rainy weather occurs during the bloom period.

Hormone-Type Sprays in the East

In the East as in the West, the use of sprays for thinning apples has given varied results. Because of the frost problem, hormone-type sprays, which can be applied after blossoming, have been favored in the East, but it has been difficult to duplicate favorable results. Tree condition and environment change from one year to another. When weather and other variables are not ideal, leaf injury and overthinning frequently result.

First use in orchards of a hormone material, naphthaleneacetic acid (NAA), was made in 1939, when it was found that they would delay the drop of ripening apples. This led to attempts in 1941 and later to try early-season applications to increase the set on apple trees. NAA was used on Starking apple trees at dilutions of 10 and 50 p.p.m. (parts per million) and naphthylacetamide at 50 p.p.m. The two concentrations of NAA reduced the number of clusters setting fruit by 15 and 77 percent respectively and the amide reduced them by 34 percent. NAA at 10 p.p.m. caused slight injury to young foliage and at 50 p.p.m. caused severe curling and scorching of leaves, whereas the amide at 50 p.p.m. caused no visible injury. Trials in 1943 in which both chemicals were used on Starking apples also showed progressive reduction in fruit set depending on the concentrations applied.

Guided by these results, research was begun in 1943 and 1944 to use these hormone chemicals as fruit thinners. At heavy concentrations of 100 and 300 p.p.m., NAA seriously overthinned Arkansas Black, Delicious,

and Gano varieties, damaged the foliage, and almost eliminated a crop. Both naphthaleneacetic acid and naphthylacetamide caused thinning, but the acid was more drastic in its action than the amide. Experiments were then tried as to the best time and concentration for applying these thinners. The greatest thinning, sometimes too severe, occurred when a spray containing NAA was applied at full bloom. An application just after this stage was often sufficient for good commercial practice. Naphthylacetamide, when applied 10 days to 2 weeks after petal fall, caused many undersized apples of 1/2 to 1 inch in diameter to remain on the tree; they never developed to normal size.

Both acid and amide are selective in their thinning effects. Soon after the bloom period, fruits on the weakest wood, those near the trunk, and those that have been shaded drop off. This selectivity and a wide choice in timing naphthaleneacetic acid and naphthylacetamide sprays have made them popular in frost-prone areas.

The mechanism by which a hormone-type chemical can make fruits drop at the beginning of the season and stop them from dropping at harvest has aroused much curiosity among scientists. Wisconsin researchers concluded in 1950 that naphthaleneacetic acid causes a heavy early set, holds the tiny fruits on longer than unsprayed trees, and that nutritional competition then causes sprayed trees to drop more fruits than they normally would. Missouri scientists reported in 1953 that, among other causes, NAA provides "a strong and prolonged inhibition" of embryo development when the spray is applied at the 5- to 10- cell stage of seed growth. They found that there were fewer seeds in dropped fruits than in those that stayed on the tree. A British investigator established that NAA spray applied during bloom prevents fertilization of blossoms and that spray applied after blossoming causes seeds to abort and the fruit to drop. Also, weak or shaded spurs normally carry fruits with few seeds, and such fruits, with less "seed value," are more susceptible to the spray than those that grow on vigorous wood in well-exposed positions. However, much remains to be learned of the complicated mechanism by which hormone-type chemicals cause thinning.

Experiments at the Agricultural Research Center, Beltsville, Md., 1953-56, show that a detergent, polyoxyethylene sorbitan monolaurate (Tween 20),² when used as a solvent and wetting agent for naphthaleneacetic acid sprays, makes it possible to decrease greatly the amount of NAA used in the spray. In fact, the detergent causes significant thinning when used alone. In the frosty spring of 1956, 2 p.p.m. of NAA with the detergent almost ideally thinned Golden Delicious trees in one orchard and did a good job on Delicious and Rome Beauty trees in another. Concentrations as high as 20 to 30 p.p.m. of NAA are customarily used without the detergent on hard-to-thin varieties like Golden Delicious. Using NAA with the detergent these experiments gave good results with concentrations as low as 2 to 5 p.p.m.

Another series of experiments at Beltsville proved that frost or near-frost, either before or after spraying, increases the permeability of leaves and causes them to absorb greater quantities of the hormone-type thinning agent, thus increasing the severity of the thinning. Until this research was done, the general impression prevailed that high temperatures were best for leaf absorption. After Wealthy seedlings had been exposed to a temperature of 28° F. for 1/2, 1, and 2 hours, NAA tagged with radioactive carbon

²Mention of this product does not constitute an endorsement by the U. S. Department of Agriculture over other products or a guaranty or warranty of the standard of this product--it was the detergent used in these experiments.

14, plus the detergent, was applied in measured amounts to the leaves. Two days later the leaves were removed, the outside deposit washed off, and radioactivity of the absorbed NAA was measured. Absorption averaged 34 percent in leaves not frosted and 60 percent in those kept at 28° for 2 hours.

The capacity of leaves to absorb NAA with and without the detergent was also measured by the same radioactive method. Without detergent, 2.8 percent of the NAA was absorbed in 1 hour and the amount ranged upward to 4.7 percent in 48 hours. With detergent 2.4 percent of the NAA was absorbed in 1 hour after application and 27.0 percent in 48 hours. The under surfaces of leaves absorbed significantly more of the spray than upper surfaces in both instances: 3.4 percent of the NAA without detergent was absorbed in 48 hours by upper leaf surfaces and 6.0 percent by under surfaces. With detergent, after 48 hours, the percentages were 20.4 and 33.6. This indicates that the under surfaces of leaves absorb NAA more readily than upper surfaces, but that both surfaces are effective.

Recommendations

The following recommendations on the use of hormone or growth-regulating chemicals for thinning in the East are based on results of many experiments by research workers and trials by growers. The grower must decide on the basis of his apparent crop whether to use chemical thinning. If he decides to use it, these guide lines should be helpful:

¶ Some varieties, notably Baldwin, Duchess of Oldenberg, Golden Delicious, Wealthy, and York Imperial, characteristically set heavy crops of fruit in "on" years, thereby showing a marked tendency to be biennial. They have generally responded well to naphthylacetamide at 50 p.p.m., applied at petal fall or not more than 5 days thereafter.

¶ In areas where frost is too much of a hazard to apply thinning sprays near petal fall, NAA may be used at a later date. Good results on the varieties just named, except the Duchess of Oldenberg, have been usually obtained by spraying with a concentration of 15 to 20 p.p.m. 15 to 25 days after petal fall. NAA causes some leaf bending and drooping at these concentrations. Growers may well experiment with using the detergent Tween 20 at 1 pint per 100 gallons plus NAA at a concentration of 2 p.p.m. In experiments, this formulation has given satisfactory fruit thinning without the leaf injury that occurs when stronger concentrations of NAA are used alone.

¶ Both the acid and amide sprays are more drastic in their effects when frost occurs before or after application. There is apparently little danger of overthinning with the amide. But, if the acid is used and there has been frost between blossoming and the time the NAA is applied, its concentration should be reduced to about 10 p.p.m.

¶ Under favorable weather conditions, with no frost and not much rain, the amide may not thin sufficiently. This is especially true with the varieties Wealthy and Golden Delicious. Ten days after application, the fruit that drops following amide application is usually smaller in size than the fruit that remains on and the seeds are usually yellow. A careful examination of the fruit set of amide-sprayed trees should be made 10 days to 2 weeks after spraying. If thinning is insufficient and if no temperatures near freezing have occurred, NAA may be applied at a concentration of about 15 p.p.m.

- ¶ A number of important varieties grown in the eastern States normally set only moderate crops, and spray thinning is usually not necessary. They include Delicious, McIntosh, Rome Beauty, and Stayman. Generally a moderate amount of hand thinning is sufficient for these varieties.
- ¶ Another group of varieties is intermediate in their tendency to set and in their need for thinning. They include Grimes Golden, Jonathan, Rhode Island Greening, and Winesap. If they carry heavy bloom and conditions for fruit set are favorable, chemical thinning is often valuable. Naphthylacetamide spray may be used up to 5 days after petal fall, or NAA at 15 p.p.m. 15 to 20 days after petal fall.
- ¶ Two very early varieties, Early McIntosh and Yellow Transparent, are difficult to thin with either the acid or the amide. Both tend to set heavily, are strongly biennial, and have a short season for fruit development. The hormone-type chemicals not only fail to thin sufficiently in most tests but have a tendency to cause softening of the fruit. Eastern growers having these varieties might well try some of the dinitro sprays at the bloom stage, even at the risk of injury from frost following application.

SPRAYS USED ON OTHER FRUITS

Pears

PEARS are generally quite susceptible to injury from hormone-type or growth-regulating chemicals. Because of this, tests in the West have been confined to the dinitro compounds (Elgetol and Krenite³) applied during the blossoming period. These materials have proved fairly satisfactory from the standpoint of moderate reduction in fruit set, but foliage injury is frequently a problem, particularly when rainy weather follows spray applications. In order to reduce leaf burning to a minimum, under most conditions, it is not advisable to use Elgetol at a concentration greater than 2/3 to 1 pint per 100 gallons. Timing of the spray application is similar to that for apples. The most effective thinning is usually obtained when 4 to 5 blossoms per spur cluster are open.

As frequently pointed out, successful use of thinning sprays is predicated on the assumption that fruit set will be in excess of the amount necessary for an adequate crop. When the set of pears is limited by lack of cross pollination or unfavorable weather, thinning sprays may cause greater set reduction than is desired. When adequately pollinated, the Bartlett variety under western conditions appears to have a greater margin of safety than most varieties of apples. The sensitivity of the foliage to injury is the chief reason why the sprays are not generally used on a commercial basis.

Apricots

Results of research in California and Washington indicate considerable promise in the use of dinitro sprays for thinning Royal and Tilton varieties of apricots.

The best time to spray apricots is when about 60 percent of the blossoms are open, but the timing may be delayed in event of adverse weather.

³ Mention of these products does not constitute an endorsement by the U.S. Department of Agriculture over other products or a guaranty or warranty of the standard of the products.

Recommended concentration for apricots is 1-1/2 pints of sodium dinitro cresylate to 100 gallons of water for Blenheim and Tilton varieties; 1 pint per 100 gallons for Wenatchee Moorpark. The risk of overthinning may be lessened by reducing the concentration or by delaying the spray application until full bloom or 1 to 2 days thereafter.

Wenatchee Moorpark, principal commercial variety in Washington, can be successfully thinned with the concentration just given. Sometimes, however, for no known reason, this variety sets less than enough blossoms for a good crop, and overthinning may result if a thinning spray is used.

Plums

Prune plums in California have been successfully thinned with dinitro sprays at a concentration of 1 quart of sodium dinitro cresylate to 100 gallons of water. Size of fruit was markedly increased by thinning, but sometimes at the expense of a lower yield. Greatest thinning is accomplished when about 90 percent of the blossoms are open. Caution should be exercised to prevent overthinning.

Promising results have been obtained with dinitro sprays on thinning Beauty, Kelsey, Santa Rosa, Wickson, and certain other varieties of Japanese plums that have a biennial tendency. Lower concentrations are needed for these plums than for apricots.

Peaches

Hand thinning of peaches has been practiced for many years. Various tools are used to assist in hand thinning, including brooms with wire "bristles" to sweep off the blossoms and a piece of rubber hose mounted on a pole or a rubber hammer on a 3- or 4-foot handle to jar off the young fruits. Pruning is another method by which many blossoms are removed along with the weaker wood. The problem is somewhat different from that with apple blossoms because peach blossoms set singly rather than in clusters, the buds form on new growth, and peaches show very little tendency to biennial bearing. Because of their early blooming habits, peaches encounter more of a frost hazard than apples.

In the Northwest, where frost is infrequent, dinitro sprays have been used with fair success in thinning peaches. The ARS scientist at the Tree Fruit Experiment Station, Wenatchee, Wash., recommended in 1955 that 1 quart of sodium dinitro cresylate be used in 100 gallons of water for thinning all varieties of peaches except Elberta and J.H. Hale. The recommendations for Elberta were 1-1/2 pints per 100 gallons, and for J.H. Hale 1 pint. For greater thinning, the spray should be applied when 60 to 75 percent of the blossoms are open. Exact timing is more important in spray thinning peaches and other stone fruits than is the case with apples.

As with apples, complete thinning is not recommended, but the hazard of overthinning is not so great: peaches grow larger on well-thinned trees, and a reduced crop of large fruit may be worth more than a large crop of small ones.

There has been extensive experimentation with peaches, using various chemicals, including the hormone-type sprays. Results have been so erratic that, except for the dinitros, chemicals cannot be recommended at the present time.

Cherries

Thinning of sweet cherries with dinitro sprays is still in the experimental stage. More work is needed before these sprays can be evaluated. No work has been done on sour cherries, with which fruit size is less important.

THE OUTLOOK

BECAUSE of the high cost of hand thinning, chemical thinning of deciduous fruits is sure to increase. Fruit-thinning sprays are of such importance that a great deal of research effort is being devoted to them. Research is the only hope for unraveling the variables that attend the use of spray thinners and for developing trustworthy formulations and timing. The variables are so numerous, however, that years of horticultural research and grower experience may be required before exact recommendations can be made on materials, concentrations, and timing of applications to the many varieties of deciduous fruits.

Many materials have been tried, and more will be tested. One of the aims is to find sprays that are milder in action than either the dinitro materials or naphthaleneacetic acid--sprays that will do an effective job of thinning while causing a minimum of damage to the trees. However, as one ARS official has remarked, "it is hardly reasonable to expect that a chemical will not overthin a 'weak' set but will always thin a 'strong' set [of fruit]. Such paradoxical qualities in a chemical would be difficult if not impossible to achieve."

A New York horticulturist is of the opinion that "there will probably never be an ideal material for chemical thinning that will give satisfactory results in all varieties, in all years, and under all conditions. The factors involved in fruit set are too many and too complex to hope for such."

Nevertheless, some research results are remarkable. Tests at Beltsville, using atomic tracers, demonstrated that, contrary to popular opinion, frost or near-frost conditions make apple leaves more permeable to hormone-type thinners than warm weather. Research with detergents may make chemical thinning more dependable and less injurious to the trees.

More accurate long-range weather forecasting covering a period of several days after treatments are applied would permit a better determination of the type of treatment to use.

Grower need and demand have stimulated much of the progress made thus far. The willingness of growers to experiment and gather experience in their own orchards has added materially to the general knowledge. Their experience and careful judgment will be necessary for years to come in order to get the best use from chemical thinning sprays.

